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(54) **Locating the peaks of an impulse response in a CDMA receiver**

(57) The method comprises measuring at 23 the impulse response of a received signal and controlling the rake receiver 24a - 24d on the basis of the measured impulse response. To speed up the processing of the measurement results of the impulse response, only the minimum and maximum values and the corresponding time instants are calculated from the measured impulse response, the calculated values and time instants are stored in a memory, and the synchronization of the receiver with the received signal is controlled on the basis of these stored values.

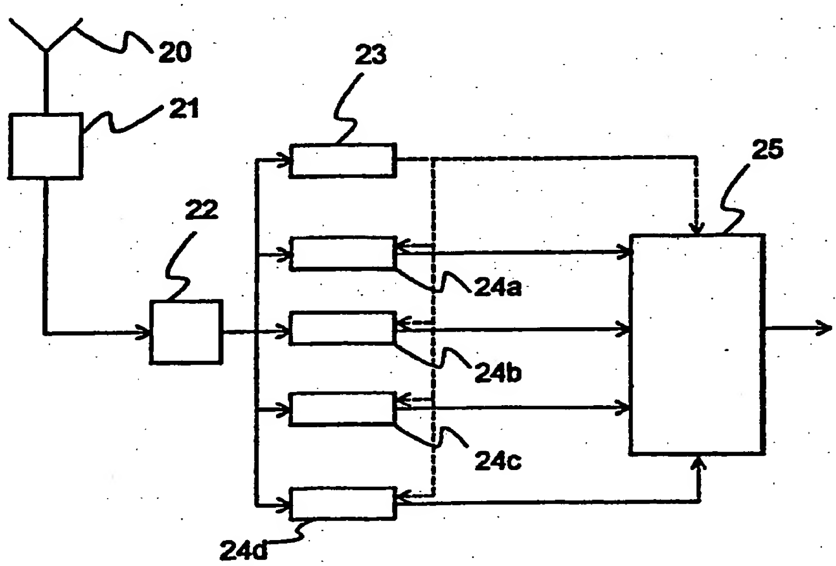

FIG. 3

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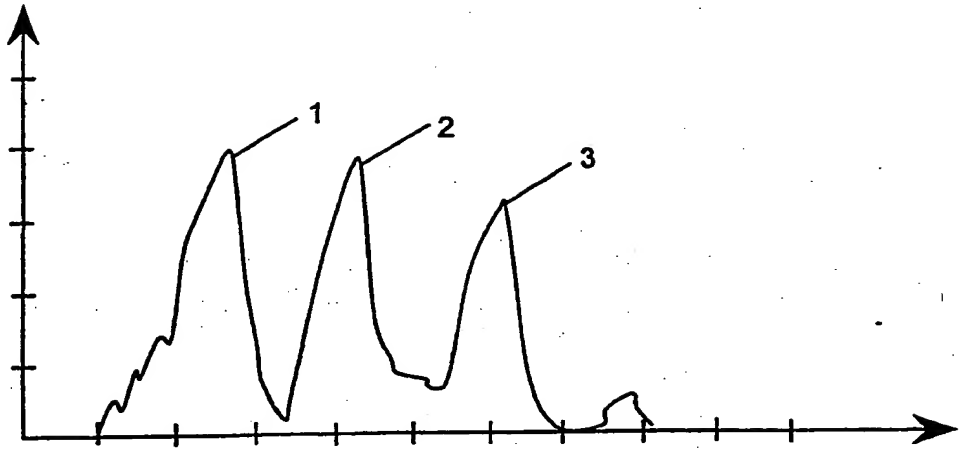

FIG. 1

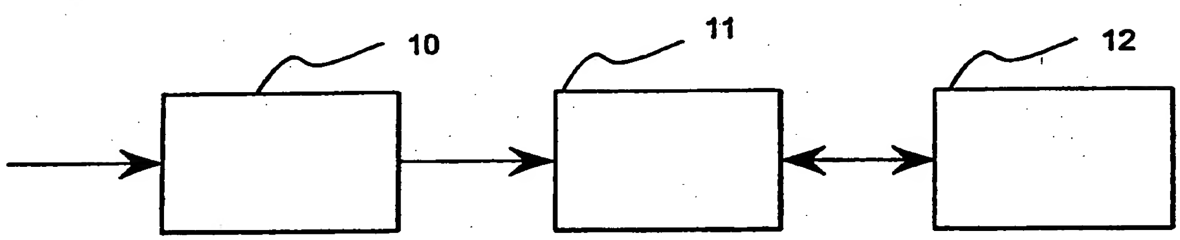

FIG. 2

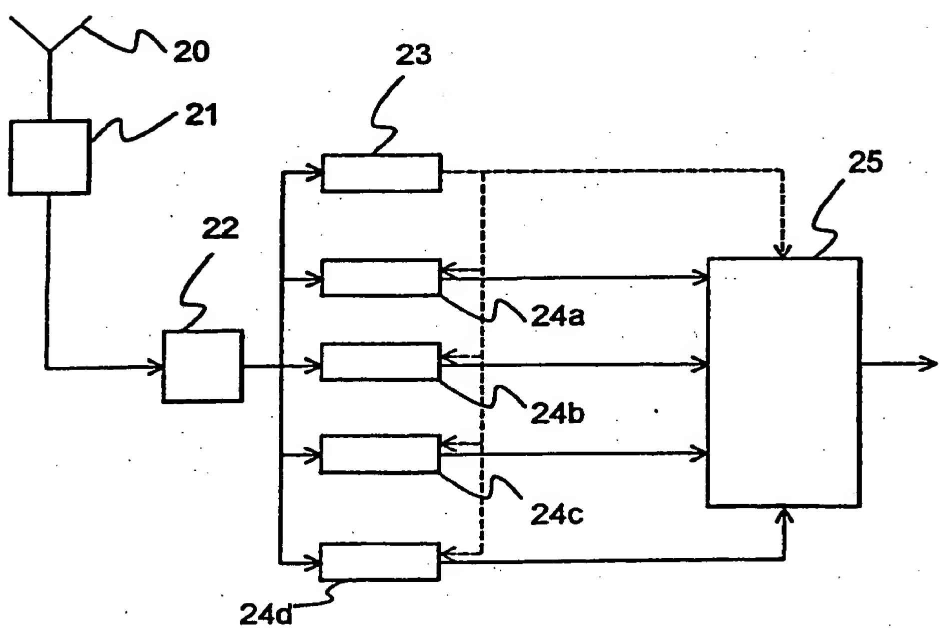

FIG. 3

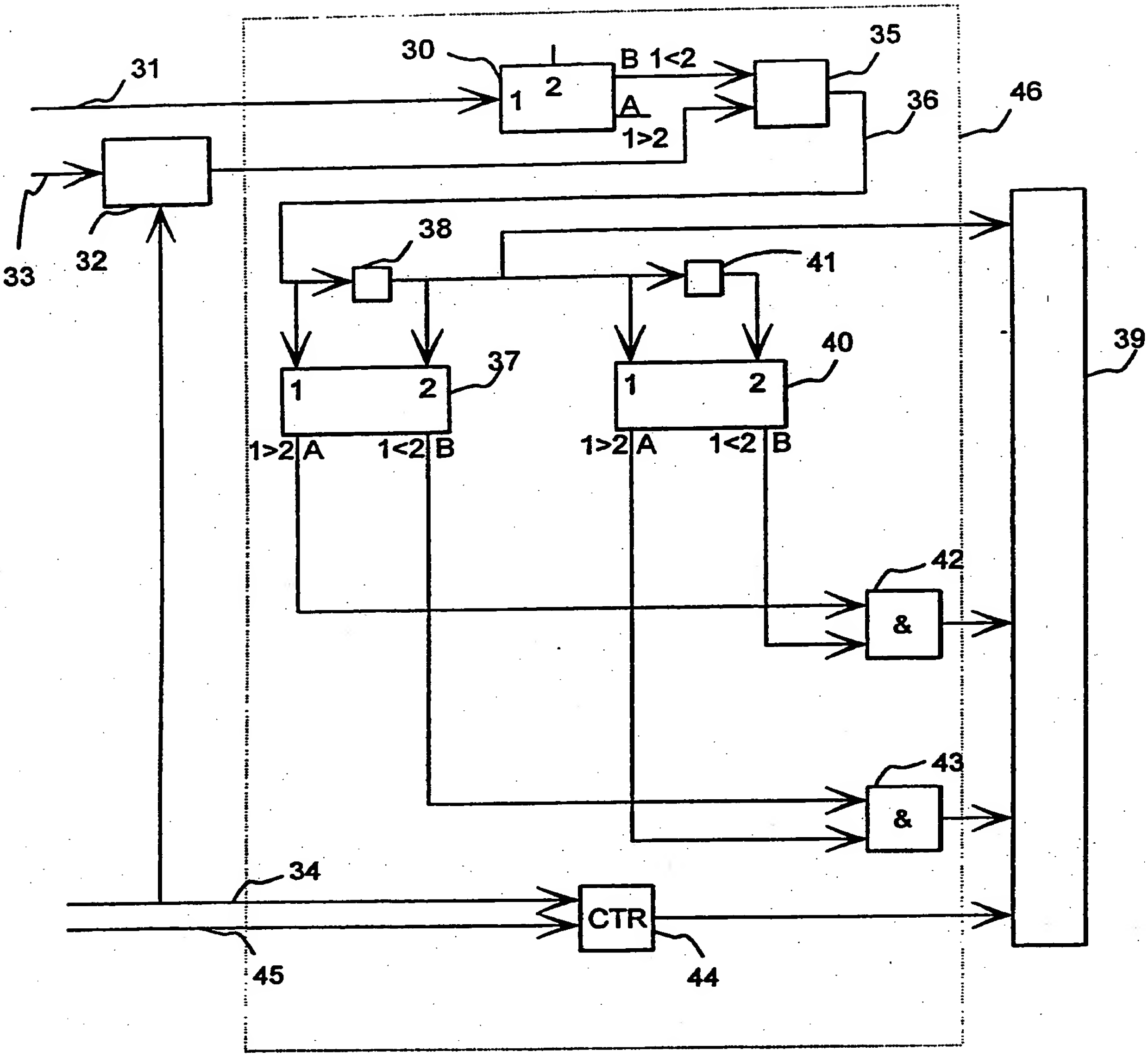
30
31
2
1
B 1<2
A
1>2
35
36
46
33
32
38
41
39
37
40
1
2
1
2
1>2 A
1<2 B
1>2 A
1<2 B
42
&
43
&
34
CTR
45
44

FIG. 4

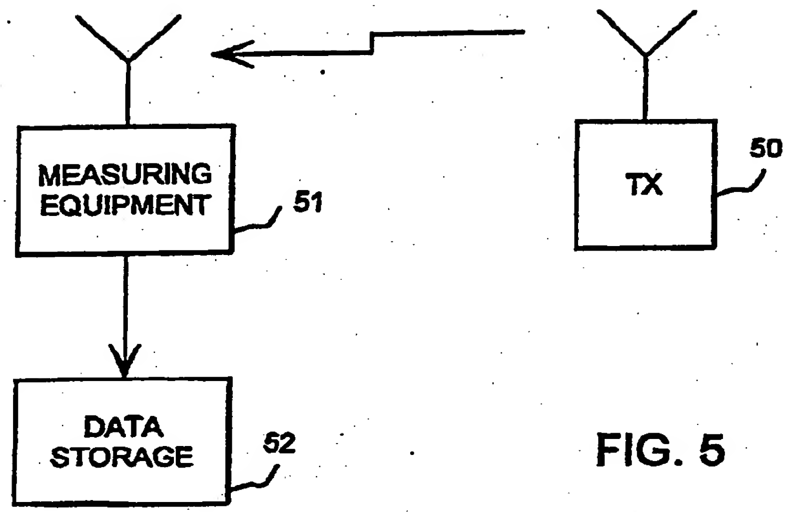
MEASURING EQUIPMENT
51
TX
50
DATA STORAGE
52

FIG. 5

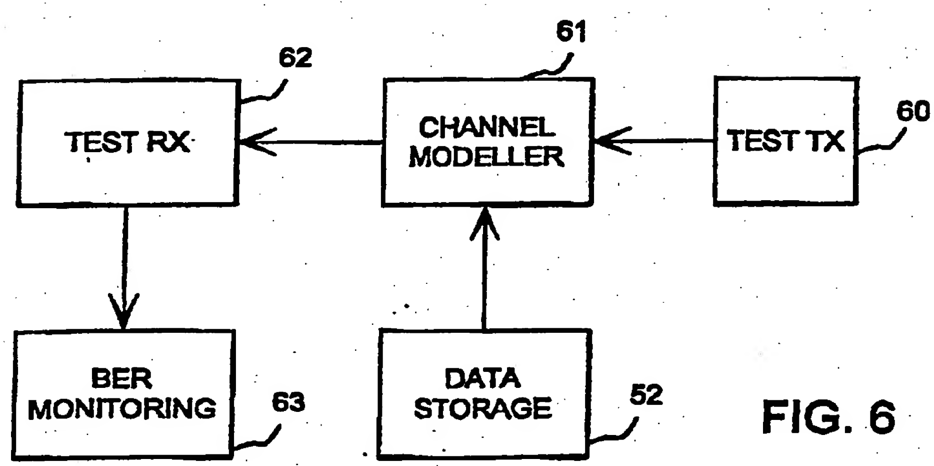
TEST RX
62
CHANNEL MODELLER
61
TEST TX
60
BER MONITORING
63
DATA STORAGE
52

FIG. 6

A method for locating the peaks of an impulse response, and a receiver

The invention relates to a method for locating the peaks of an impulse response in a CDMA receiver, the method comprising measuring the impulse response of a received signal and controlling the receiver on the basis of the measured impulse response.

CDMA is a multiple access method, which is based on the spread spectrum technique and which has been applied only recently in cellular radio systems, in addition to the prior FDMA and TDMA methods. CDMA has several advantages over the prior methods, for example spectral efficiency and the simplicity of frequency planning.

In the CDMA method, the narrow-band data signal of the user is multiplied to a relatively wide band by a spreading code having a considerably broader band than the data signal. In known test systems, bandwidths such as 1.25 MHz, 10 MHz and 25 MHz have been used. In connection with multiplying, the data signal spreads to the entire band to be used. The bit rate of the spreading code, a so-called chip rate, is thus considerably higher than the bit rate of the user data. The ratio between the chip rate and the bit rate of the user data is called the spreading ratio of the system.

All users transmit by using the same frequency band simultaneously. A separate spreading code is used over each connection between a base station and a mobile station, and the signals of the users can be distinguished from one another in the receivers on the basis of the spreading code of each user.

CDMA receivers conventionally use correlators, which are synchronized with a desired signal, which they recognize on the basis of the spreading code. In the receiver, the data signal is restored to the original band by multiplying it again by the same spreading code as during the transmitting stage. Signals multiplied by

some other spreading code do not correlate in an ideal case and are not restored to the narrow band. They appear thus as noise with respect to the desired signal. The spreading codes of the system are preferably selected in such a way that they are mutually orthogonal, i.e. they do not correlate with each other.

In a typical mobile phone environment, the signals between a base station and a mobile station propagate along several paths between the transmitter and the receiver. This multipath propagation is mainly due to the reflections of the signal from the surrounding surfaces. Signals which have propagated along different paths arrive at the receiver at different times due to their different transmission delays. This multipath propagation of the signal may be monitored in the receiver by measuring the impulse response of the received signal, the signals arriving at different times appearing in the impulse response as peaks proportional to their signal strength. Figure 1 illustrates, by way of example, a measured impulse response. The horizontal axis shows the time and the vertical axis shows the strength of the received signal. The peaks 1,2,3 of the curve indicate the strongest multipath-propagated components of the received signal.

CDMA differs from the conventional FDMA and TDMA in that the multipath propagation can be exploited in the reception of the signal. The receiver generally utilized in a CDMA system is a so-called rake receiver, which consists of one or more rake branches. Each branch is an independent receiver unit, the function of which is to compose and demodulate one received signal component. Each rake branch can be caused to synchronise with a signal component which has propagated along an individual path, and in a conventional CDMA receiver the signals of the receiver branches are preferably combined, whereupon a signal of good quality is achieved.

In addition to branches receiving multipath-propagated signal components, a rake receiver comprises a separate block for measuring the impulse response, the function of the block being to monitor and measure the impulse

response of a channel and to control the synchronization of the rake branches with the desired signal components.

In addition to the rake principle, there are also other possible ways of implementing a CDMA receiver. These receivers also necessitate measuring the impulse response of the received signal, on the basis of which the receiver is directed to synchronize with the correct signal component.

Figure 2 illustrates the conventional manner of processing the measurement results of an impulse response. In a method according to a known technique, a measuring block (10) for the impulse response, a processor unit (11), and a memory element (12) are needed. The processor reads measurement results from the measuring block for the impulse response, post-processes them, if necessary, and stores all the measured values in the memory element. When the phases of the rake branches of the receiver are to be changed, the processor searches for the maximum values of the impulse response from the memory element by means of a program, the values of the delays of the different branches of the receiver being set on the basis of these maximum values.

Assume for the sake of example that the bit rate of the system is 25 kbit/s, and the chip rate of the spreading code is 12.5 Mbit/s. The spreading ratio is thus 500. If a delay spread of 20 μs is to be measured with an accuracy of half a chip, 250 measurement results are then needed, and all these results have be to stored in the memory element. If the receiver comprises for example three different rake branches, three different maximum values have to be searched for in the results, if necessary. This operation is not difficult to carry out, but it consumes processing time and necessitates the use of a large memory element.

The purpose of the present invention is thus to implement a simpler and faster way of processing the measurement results of impulse response.

In accordance with a first aspect of the present invention there is provided a method for locating the peaks of an impulse response in a CDMA receiver, comprising measuring the impulse response of a received signal, determining the minimum and maximum values and the coresponding time instants from the measured impulse response, storing the calculated values and corresponding time instants in a memory, the synchronization of the receiver with the received signal being controlled on the basis of these stored values.

In accordance with a second aspect of the present invention there is provided a receiver comprising means for measuring the impulse response of a received signal, means for determining the minimum and maximum values and the corresponding time instants of the impulse response, means for storing the determined values and time instants, and means for controlling the synchronization of the receiver with the received signal on the basis of the stored values.

The size of the required memory element can be considerably diminished by means of the method according to the invention. This is possible, since unlike before, only the measured minimum and maximum values of the impulse response are stored in the memory instead of all the measured values. On the basis of these peaks, the delays of the different rake branches are set. Correspondingly, the valleys can be exploited so that the rake branches are not unnecessarily reserved for monitoring one peak, if adjacent peaks are close to each other.

In the following, the invention will be described in greater detail with reference to the examples according to the accompanying drawings, in which

Figure 1 shows an example, already described above, of the impulse response of a received signal,

Figure 2 shows an example, already described above, of a known manner of processing the measurement results of an impulse response,

Figure 3 shows a block diagram illustrating the structure of a rake receiver,

Figure 4 illustrates one implementation of the method according to the invention of processing the measurement results of an impulse response,

Figure 5 illustrates the implementation of the method according to the invention in connection with gathering the measurement results, and

Figure 6 illustrates the implementation of testing equipment utilizing the method according to the invention.

The method according to the present invention is applicable in all CDMA receivers where the impulse response of a channel is measured. The method can also be applied in separate devices for measuring the impulse response of a channel. In the following, the invention will be illustrated by using a rake receiver structure as an example, without however being limited thereto.

Figure 3 illustrates the structure of a rake receiver for implementation of an embodiment of the invention. A signal received by an antenna 20 is provided after radio-frequency parts 21 to an A/D converter 22. The converted signal is provided to rake correlator branches 24a to 24d, which are synchronized with the received signal components. The signal is also provided to a measuring block 23, which measures the impulse response of the received signal, the rake branches 24a to 24d being adjusted according to the impulse response. The signals of the rake branches are combined and demodulated in a block 25, wherefrom the combined signal is applied for further processing.

The measurement of the impulse response may be performed by known methods. The measurement may be performed by means of either correlators or matched filters. Measurement by correlators is performed in such a way that the spreading code is stepped with respect to the received data. A measuring block carried out by means of correlators produces one measurement result per bit clock

cycle. Correspondingly, measurement carried out by means of matched filters produces one measurement result per measurement clock cycle.

In the method in accordance with an embodiment of the invention, the minimum and maximum values of the impulse response measurement performed by means of correlators or matched filters are calculated and stored in a memory element together with time instants corresponding to the peaks. When the phases of the rake branches are to be changed, the maximum and minimum values are read from the memory element and the phases of the branches may be set to follow the strongest signals. A need to change the phases of the rake branches occurs when the impulse response of the channel changes, i.e. the propagation delays of multipath-propagated components change.

Figure 4 shows the processing block for the impulse response of a receiver implementing the method according to the invention. The block comprises three comparators 30,37,40, two AND gates 42,43 and a counter 44. The measurement of the impulse response is assumed to be performed by means of a separate pilot channel, where no modulated data is transmitted. The measurement of the impulse response is assumed to be performed in this receiver structure by means of matched filters. The measurement may also be performed by means of correlators, as mentioned above. In a measuring block 32 for the impulse response, accumulated values of I and Q channels are measured from inbound non-composed data 33, the values being further squared and added together. The calculated result is provided to the first comparator 30, where the result is compared to a predetermined threshold 31. If the result is higher than the threshold, an enabling device 35 allows it to connect to the next stages.

When three successive values exceeding the threshold are counted, it is possible to detect by means of the second and third comparator 37,40 whether the middle result is the valley or peak of the impulse response. Both peaks and valleys are stored in a memory element 39.

The value from the enabling block is connected to the input 1 of the second comparator 37, and through a delay element 38 to the input 2. Thus the inputs of the comparator always comprise two successive values. The output of the delay element 38 is connected to the memory element 39 where the value is stored if it proves to be a peak or a valley (trough), and also to the input 1 of the third comparator and through a delay element 41 to the input 2. Output A of the second comparator 37 comprising a signal indicating that the value in port 1 of the second comparator is higher than the value in port 2, and output B of the third comparator 40 comprising a signal indicating that the value in port 2 of the third comparator is higher than the value in port 1 are connected to the first AND gate 42. When the signals in both outputs go up, it is the peak of the impulse response. Output B of the second comparator 37 comprising a signal indicating that the value in port 2 of the second comparator is higher than the value in port 1, and output A of the third comparator 40 comprising a signal indicating that the value in port 1 of the third comparator is higher than the value in port 2 are connected to the second AND gate 43. When the signals in both outputs go up, it is the valley of the impulse response. The output of each AND gate 42,43 is connected to the memory element 39.

The measurement of the impulse response is started and a counter 44 is initialized by means of an identification pulse 34 passing to the measuring block 32 for the impulse response. The identification pulse 34 goes up for one chip clock cycle during one code period, i.e. the length of the spreading code. The identification pulse can be used to indicate a particular point in the spreading code, and it may be formed by means of for example counters. In addition to the identification pulse, a chip clock signal 45 forms the other input of the counter 44. The time instants of the peaks and valleys can be stored in the memory element 39 by means of the counter.

The number of the comparators can be increased, if peaks with a wider form are to be monitored.

Figures 5 and 6 illustrate the application of the method according to the invention in connection with testing transceivers. Figure 5 illustrates an example of a measurement environment where information about the impulse response of a channel is gathered. The environment comprises a measurement transmitter 50, a receiver 51 comprising the measuring equipment for the impulse response of the channel, and a data storage unit 52. The receiver 51 measures the impulse response of the channel from the signal supplied from the transmitter 50, and in accordance with the invention, stores the minimum and maximum values in the data storage unit. The measuring equipment described here may be positioned for example in a moving vehicle, whereupon it is possible to store in the memory measurement results corresponding to a real situation.

Figure 6 illustrates an example of a test arrangement comprising a transmitter 60, a receiver 62, a channel modeller 61, a BER monitoring block, and a data storage unit 52. The measured results stored by means of the method according to the invention can thus be utilized in a laboratory environment in such a way that the data storage unit 52 is connected to the channel modeller 61, by means of which a channel model corresponding to a real situation is formed. This method has the advantage that the measurement signals may be driven through the channel and the channel model at higher speeds than conventionally. Thus the testing time itself may be shortened. Since the memory of the data storage unit comprises not the entire impulse response measured but only the peaks, the size of this unit can be diminished, and on the other hand the measurement may be performed over a longer period of time.

Even though the invention is described above with reference to the example in accordance with the accompanying drawings, it is clear that the invention is not limited thereto, but it can be modified in many ways within the scope of the inventive idea disclosed.

Claims:

1. A method for locating the peaks of an impulse response in a CDMA receiver comprising measuring the impulse response of a received signal, determining the minimum and maximum values and the coresponding time instants from the measured impulse response, storing the calculated values and corresponding time instants in a memory, the synchronization of the receiver with the received signal being controlled on the basis of these stored values.

2. A method according to claim 1, wherein the receiver is carried out with a rake principle, and that the rake branches of the receiver are controlled on the basis of the stored values.

3. A method according to claim 2, wherein the phases of the rake branches of the receiver are set on the basis of the time instants corresponding to the stored maximum values of the impulse response.

4. A method according to claim 2, wherein if the time instants corresponding to two adjacent maximum values separated by the minimum point are closer together than preset time instants, only one of said maximum points is taken into consideration when the phases of the rake branch of the receiver are being set.

5. A method according to claim 1, wherein the impulse response is measured by using a separate pilot channel, where no data is modulated.

6. A method according to claim 1, wherein the receiver is a separate measuring device for the impulse channel, and that the channel modeller of the testing device of the receiver is controlled on the basis of the stored values.

7. A receiver comprising means for measuring the impulse response of a received signal, means for determining the minimum and maximum values and the

corresponding time instants of the impulse response, means for storing the determined values and time instants, and means for controlling the synchronization of the receiver with the received signal on the basis of the stored values.

8. A receiver according to claim 7, wherein the receiver comprises a number of rake receiver branches, which each receive their own multipath-propagated signal component, and that the receiver comprises means for controlling the rake branches of the receiver on the basis of the stored values.

9. A receiver according to claim 7, wherein the means for determining the minimum and maximum values and the corresponding time instants of the impulse response comprise a first comparator, a desired threshold value being connected to the input of said first comparator, and an enabling device, the first input of which is the output of the first comparator and the second input of which is the output of the measuring device for the impulse response, the inputs of said measuring device being formed by non-composed data and an identification pulse, and the output of said enabling device being formed by the value of the impulse response if it exceeds the given threshold, and which output is connected to an input 2 of a second comparator and to a first delay device, the value from the output of said delay device being connected to a memory device, to an input 1 of the second comparator, to an input 2 of a third comparator, and to a second delay device, the output of said device being connected to the input 1 of the third comparator, and a maximum value indicator to the input of which output port A of the second comparator and output port B of the third comparator are connected, a signal in port A indicating that the value in port 1 of the second comparator is higher than the value in port 2, and a signal in port B indicating that the value in port 2 of the third comparator is higher than the value in port 1, and the output of said maximum value indicator showing a signal when both inputs if the indicator comprise a signal, and which output is connected to the memory device, and a minimum value indicator to the input of which output port B of the second comparator and output port A of the third comparator are connected, a signal in port B indicating that the value in port 2 of the second comparator is higher than

the value in port 1, and a signal in port A indicating that the value in port 1 of the third comparator is higher than the value in port 2, and the output of said minimum value indicator showing a signal when both inputs of the indicator comprise a signal, and which output is connected to the memory device, and a counter, the inputs of which are the identification pulse and a clock signal.

10. A receiver according to claim 7, wherein the means for measuring the impulse response are carried out by means of matched filters.

11. A receiver according to claim 7, wherein the means for measuring the impulse response are carried out by means of correlators.

12. A receiver according to claim 7, wherein the receiver is a separate measuring device for the impulse channel.

13. A receiver substantially as hereinbefore described with reference to Figures 3 and 4 of the accompanying drawings.

14. A method substantially as hereinbefore described with reference to figures 3 and 4 of the accompanying drawings.

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The Patent Office

Application No:	GB 9502104.4	**Examiner:**	Keith Williams
Claims searched:	1-14	**Date of search:**	25 April 1995

Patents Act 1977
Search Report under Section 17

Databases searched:

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:

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Int Cl (Ed.6): H04B 1/66, 1/69, 7/216, 7/26; H04J 13/00, 13/02; H04L 23/02, 25/02, 25/03, 25/49, 25/497, 27/22

Other: online WPI

Documents considered to be relevant:

Category	Identity of document and relevant passage	Relevant to claims
A,E	GB2282300A Northern Telecom - see abstract	
A	GB2268371A Roke Manor Research - see abstract	

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		E	Patent document published on or after, but with priority date earlier than, the filing date of this application.
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